Evaluation of Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep: V. Reproduction of F_1 ewes in spring mating seasons[1,2]

E. Casas,[3] B. A. Freking, and K. A. Leymaster

USDA, ARS, US Meat Animal Research Center, Clay Center, NE 68933-0166

ABSTRACT: Objectives were to estimate effects of sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed [Composite III (CIII) and northwestern whiteface (WF)], mating season (March and May), and their interactions on reproductive traits of mature F_1 ewes in spring mating seasons. A total of 1,099 F_1 ewes produced 1,754 litters of 2,995 lambs from exposures to Suffolk rams during March and May mating seasons in 1995 through 1999. Fertility rate and ewe longevity were measured. Number born and litter birth weight were recorded, and number and weight at weaning and 20 wk of age were analyzed separately for dam- and nursery-reared litter mates. Total productivity from 4 to 6 yr of age for each ewe entering the breeding flock was calculated as the sum of 20-wk weights for dam-reared lambs and separately for nursery-reared lambs. Interactions of sire breed × mating season, ewe age × mating season, and ewe age × dam breed were often significant. Interactive effects of sire breed and mating season on fertility rate ($P < 0.001$) were primarily due to differences in magnitude. Fertility rates of sire breeds for March and May matings, respectively, were 92 and 89% for Romanov, 91 and 72% for Finnsheep, 90 and 52% for Texel, 88 and 52% for Montadale, and 83 and 62% for Dorset. Sire breed × mating season also affected number born ($P < 0.03$); March and May values were 2.12 and 2.05 for Romanov, 2.00 and 1.94 for Finnsheep, 1.39 and 1.41 for Texel, 1.37 and 1.51 for Montadale, and 1.37 and 1.55 for Dorset, respectively. Interaction of sire breed × dam breed on fertility rate ($P < 0.01$) was due to change in rank as well as magnitude. Romanov- and Dorset-sired ewes out of CIII dams had greater fertility rates than Romanov- and Dorset-sired ewes out of WF dams. The opposite situation existed for ewes by Finnsheep, Texel, and Montadale sires. Differences between dam breeds (CIII and WF) in total productivity of dam-reared lambs were not detected, whereas ewes exposed in March (78 kg) were more productive ($P < 0.01$) than those exposed in May (68 kg). Means of sire breeds for total productivity of dam-reared lambs were 47, 65, 70, 70, and 111 kg for Texel, Montadale, Dorset, Finnsheep, and Romanov, respectively ($P < 0.001$). Superior reproduction of Romanov-sired ewes was primarily due to greater fertility rate and prolificacy at each mating season and ewe age. Use of Romanov-crossbred ewes would increase fertility during spring mating, an important constraint of the sheep industry.

Key Words: Breeds, Fertility Rate, Reproduction, Sheep, Spring Mating

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Introduction

Breed diversity is a valuable resource that can be managed to express individual and maternal heterosis effects as well as effects of complementarity. These genetic effects can be exploited in terminal crossbreeding systems that use sire breeds to complement characteristics of crossbred ewes, thereby greatly improving efficiency of commercial lamb production (Dickerson, 1969). Comprehensive evaluation of breeds is required to provide critical information that determines the appropriate use of breeds in crossbreeding systems to meet specific production environments and marketing goals. This logic provided justification for a large-scale experiment to comprehensively evaluate the Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep. The well-characterized Dorset and Finnsheep served as standards of comparison for general purpose and prolific breeds, respectively, whereas relative performance in North America of Romanov, Texel, and Montadale was less documented. Crossbred ewes sired

[1]Larry Young (deceased) provided leadership for conceiving, designing, and conducting this experiment.

[2]Mention of a trade name, proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

[3]Correspondence: P.O. Box 166 (phone: 402-762-4168; fax: 402-762-4173; e-mail: casas@email.marc.usda.gov).

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Table 1. Number of F_1 ewes joined at 4 yr of age by breed cross, year of birth, and fall mating season[a]

	1991			1992			1993			Marginal
Breed cross[b]	August	October	December	August	October	December	August	October	December	totals
Dorset × CIII	4	9	13	15	9	16	10	11	5	92
Dorset × WF	8	8	12	13	6	15	16	13	12	103
Finnsheep × CIII	14	12	12	7	14	17	12	15	16	119
Finnsheep × WF	7	5	5	11	9	15	17	6	10	85
Romanov × CIII	3	22	11	15	16	17	25	12	12	133
Romanov × WF	4	8	17	20	11	8	24	14	15	121
Texel × CIII	10	13	12	6	6	15	14	4	14	94
Texel × WF	9	10	13	12	14	22	15	10	8	113
Montadale × CIII	11	14	15	17	12	8	11	15	14	117
Montadale × WF	9	12	13	17	13	14	19	8	17	122
Marginal totals	79	113	123	133	110	147	163	108	123	1,099

[a]Crossbred ewes were joined with rams in the fall to lamb at 1, 2, and 3 yr of age and then were assigned randomly within sire, dam breed, and fall mating season to either March or May mating groups at 4 yr of age.
[b]Sire breed is listed first; dam breed is listed second. CIII = Composite III and WF = northwestern whiteface.

by rams of these five breeds were evaluated for reproductive traits at 1, 2, and 3 yr of age following August, October, and December mating seasons (Casas et al., 2004).

One important economic constraint of the sheep industry is the seasonal nature of ewe fertility (Wang and Dickerson, 1991c; Notter, 2002). Seasonality results in widespread lambing during the winter and spring seasons followed by marketing of lambs in summer and fall. A priority of the American sheep industry is to identify and/or develop breeds that are less seasonal in fertility. Therefore, the next phase of the experiment focused on ewe fertility during spring mating seasons. The specific objective was to estimate effects of sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed (Composite III and northwestern whiteface), mating season (March and May), and their interactions on reproductive traits of mature F_1 ewes in spring mating seasons.

Materials and Methods

General Experimental Design

Freking et al. (2000) described the design of the first phase of the experiment. Briefly, Dorset, Finnsheep, Romanov, Texel, and Montadale rams were mated to Composite III and northwestern whiteface ewes for 3 yr during three separate fall mating seasons of 35 d beginning approximately August 5, October 15, and December 15 each year (Table 1). A total of 101 rams (20 Dorset, 21 Finnsheep, 19 Romanov, 22 Texel, and 19 Montadale) produced daughters that contributed data for this experiment. The Composite III flock was developed at the US Meat Animal Research Center from a ½ Columbia, ¼ Hampshire, and ¼ Suffolk crossbred foundation (Leymaster, 1991). The northwestern whiteface ewes of Rambouillet background were purchased from producers in Montana.

The experiment was designed to produce 20 F_1 ewe lambs from each sire breed × dam breed combination in each season each year for the evaluation of reproductive traits, a total of 1,800 ewes. All F_1 ewes were group-mated for 35 d to fertile Suffolk rams, so as to lamb at 1, 2, and 3 yr of age. Reproductive traits following August, October, and December mating seasons were reported for the 10 types of F_1 ewes by Casas et al. (2004).

This phase of the experiment evaluated reproductive performance of mature F_1 ewes during spring mating seasons. After weaning lambs at 3 yr of age, 1,099 sound ewes were sorted by sire, dam breed, and fall mating season (Table 1) and assigned randomly to spring mating seasons. This approach ensured that both genetic and environmental effects were similar for ewes assigned to either March or May mating seasons. Ewes were group-mated to Suffolk rams at 4, 5, and 6 yr of age. Ewes born in 1991 lambed in 1995, 1996, and 1997; ewes born in 1992 lambed in 1996, 1997, and 1998; and ewes born in 1993 lambed in 1997, 1998, and 1999.

Flock Management and Description of Traits

Crossbred ewes were managed together as a single group within each season. Ewes were exposed in three consecutive years. All sound and healthy ewes were exposed at 4, 5, and 6 yr of age beginning about March 12 and May 14. Ewes were exposed to vasectomized teaser rams for approximately 16 d before exposure to fertile Suffolk rams. Ewes were multisire-mated to Suffolk rams; the ratio was approximately one ram per 20 ewes. Rams had been photoperiod-treated and semen-tested. The photoperiod treatment consisted of housing rams in a light-controlled building for 6 wk before use; 8 h of light were provided per day. Each mating season was 42 d in length, except in 1996, when both March and May seasons were 35 d. Barren ewes were not culled; therefore, there was not any direct selection pressure for spring fertility.

Ewes were on brome pasture during gestation and were given supplemental feed only as needed to meet nutritional requirements. Ewes were treated for parasites, vaccinated against type C and D enterotoxemia,

and given vitamins A, D, and E. Approximately 1 wk before parturition, ewes were moved to a building with an elevated woven-wire floor, where they lambed. Number born and litter birth weight were recorded within 24 h after lambing. Nursery facilities were used to artificially rear 7% of single-born lambs, 19% of twin-born lambs, 35% of triplet-born lambs, and 53% of quadruplet-born lambs. Only a few ewes were given the opportunity to rear three lambs. Of artificially reared lambs, 45% were moved to the nursery within 24 h of birth. All males were castrated at approximately 14 d of age. All lambs were offered a total-mixed creep diet (2.90 Mcal of ME/kg of DM with 17.5% CP, DM basis) by approximately 14 d of age. At weaning (59 d for lambs reared by the ewe and 30 d for lambs reared in nursery), the numbers of lambs reared by the ewe and in the nursery were recorded. Weaning weight was recorded for each lamb and adjusted for variation in age, to 59 and 30 d for dam- and nursery-reared lambs, respectively. Litter weights of lambs reared naturally by the ewe and in the nursery were calculated separately.

After weaning, lambs reared in the nursery were brought to the finishing pen with their contemporaries. All lambs were kept in finishing pens and switched from the creep diet to a total mixed diet (2.96 Mcal of ME/kg DM with 14.5% CP, DM basis) at approximately 10 wk of age. Numbers of lambs at 20 wk of age reared by the ewe and in nursery were tabulated for each ewe. Lamb weights were adjusted to 20 wk of age, and dam- and nursery-reared litter weights of lambs were calculated both per ewe lambing and per ewe exposed.

Each record was considered a trait of the ewe. Traits measured to weaning were fertility rate, number born, litter birth weight, number of dam-reared lambs at weaning, number of nursery-reared lambs at weaning, dam-reared litter weaning weight, and nursery-reared litter weaning weight. Traits measured at 20 wk of age were number of dam-reared lambs, number of nursery-reared lambs, dam-reared litter weight per ewe lambing, nursery-reared litter weight per ewe lambing, dam-reared litter weight per ewe exposed, and nursery-reared litter weight per ewe exposed. Total productivity from 4 to 6 yr of age for each ewe entering the spring breeding flock was calculated as the sum of 20-wk weights for dam-reared lambs and separately for nursery-reared lambs. For example, a ewe that reared one lamb (38 kg at 20 wk of age) at 4 yr of age, twins (35 and 42 kg at 20 wk of age) at 5 yr of age, and then was culled had a value of 115 kg for total productivity. Traits measured at weaning and 20 wk of age were defined separately for dam-reared and nursery-reared lambs to evaluate reproduction of crossbred ewes in different production systems.

Total productivity was used as a natural index of overall reproductive performance, determined by phenotypic variation in component traits of fertility rate, prolificacy, maternal ability, growth, and longevity. Fertility rate was measured as a binary trait, indicating that a ewe present at the beginning of a lambing season either lambed (1) or did not lamb (0). Longevity of each ewe was measured as a binary trait based on presence (1) or absence (0) of the ewe in the breeding flock at the end of the experiment. Ewes were culled only for reasons that adversely affected their ability to produce or raise lambs. Primary culling reasons were mastitis, pneumonia, poor health, and unilateral mammary failure.

A total of 2,253 records were analyzed for fertility rate, dam-reared litter weight at 20 wk of age per ewe exposed, and nursery-reared litter weight at 20 wk of age per ewe exposed. A total of 1,754 records were analyzed for traits based on number of ewes lambing. A total of 1,052 records were analyzed for total productivity and longevity per ewe entering the spring breeding flock (Table 2). Records of 33 ewes that died during an October 1997 blizzard and 14 ewes that were accidentally bred during January 1999 were deleted for total productivity and longevity because these 47 ewes did not have normal opportunity to lamb at 4, 5, and 6 yr of age.

Statistical Analyses

Data were analyzed with the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). The model included fixed effects of year of birth of the ewe (1991, 1992, and 1993), sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed (Composite III and northwestern whiteface), ewe age (4, 5, and 6 yr), spring mating season of the ewe at 4, 5, and 6 yr of age (March or May), and all possible two-way interactions among these fixed effects. The effect of fall mating season of the ewe at 1, 2, and 3 yr of age (August, October, and December) also was included as a fixed effect. Fall mating season × ewe age was fitted for fertility rate, but analyses of other traits did not include any interaction involving fall mating season. The three-way interaction of sire breed × dam breed × spring mating season also was included in the analysis for all traits. The random effect of sires within year of birth and sire breed was included. Age was treated as a repeated effect of ewe within year of birth, sire breed, dam breed, and mating season. Effects of year of birth, sire breed, and year of birth × sire breed were tested with the sire within year of birth and sire breed mean square and were considered approximations because of unbalanced data. Effects of ewe age and its interactions were tested against the residual mean square. All remaining effects were tested with the effect of ewe within year of birth, sire breed, dam breed, and mating season. A compound symmetry structure was assumed for the residual (co)variance matrix. The Satterwaite option was used to approximate df. The fixed effect of ewe age and its use as a repeated measurement were removed from the model when analyzing total productivity and longevity. Pairwise differences between means were tested for sire breed and fall mating season if *F*-tests of interactions were not significant and main effects of sire breed or

Table 2. Number of F_1 ewes into breeding at 4, 5, and 6 yr of age and completing the experiment by breed cross and spring mating season

	March				May			
Breed cross[a]	4	5	6	Final	4	5	6	Final
Dorset × CIII	44	29	15	13	46	34	20	17
Dorset × WF	49	31	18	12	53	42	31	28
Finnsheep × CIII	58	37	12	12	55	39	22	20
Finnsheep × WF	37	29	13	12	42	25	12	10
Romanov × CIII	65	57	36	29	60	51	28	23
Romanov × WF	56	48	23	18	55	43	24	23
Texel × CIII	49	33	15	14	43	21	16	16
Texel × WF	54	30	19	14	54	35	20	18
Montadale × CIII	60	50	31	25	55	37	28	23
Montadale × WF	61	40	25	23	56	40	25	22
Marginal totals	533	384	207	172	519	367	226	200

[a]Sire breed is listed first; dam breed is listed second. CIII = Composite and WF = northwestern whiteface.

fall mating season were significant. Probability values are nominal and are not corrected for multiple testing.

Results

Levels of significance and least squares means are reported for effects of sire breed, dam breed, spring mating season, fall mating season, and two-way interactions of spring mating season × sire breed (Tables 3–6). The interaction of sire breed × dam breed for fertility rate also is reported (Figure 1). Interactions of dam breed × spring mating season on all traits, and sire breed × dam breed × spring mating season on all traits were not significant. Estimates of age of ewe effects were not reported because only mature ewes were used. Estimates of year effects were not reported because year effects cannot be predicted to recur in the future, and it is appropriate for producers to make decisions about sire breeds, dam breeds, and mating seasons based on information averaged over several years.

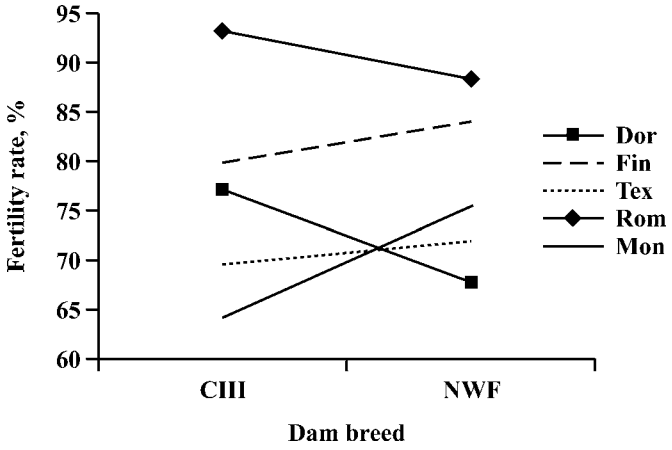

Figure 1. Interaction of sire breed and dam breed for fertility rate of F_1 ewes. Dor = Dorset, Fin = Finnsheep, Tex = Texel, Rom = Romanov, and Mon = Montadale. CIII = Composite III; NWF = northwestern whiteface.

Fertility Rate

The interaction of sire breed × dam breed was detected ($P < 0.01$) for fertility rate (Figure 1). Finnsheep-, Texel-, and Montadale-sired ewes had a greater fertility rate when dams were northwestern whiteface rather than Composite III. In contrast, Dorset-, and Romanov-sired ewes had a greater fertility rate when dams were Composite III instead of northwestern whiteface.

The interaction of spring mating season × sire breed was detected ($P < 0.001$) for fertility rate (Table 3). Romanov-sired ewes maintained a fairly consistent fertility rate through the spring mating seasons. Ewes sired by other breeds had greater fertility rates during the March mating season than during the May mating season.

Traits Measured to Weaning

The interaction of spring mating season × sire breed was detected ($P < 0.05$) for number born (Table 3). Number born to Romanov- and Finnsheep-sired ewes decreased slightly from March to May mating seasons, whereas ewes by Dorset, Texel, and Montadale sires had a greater number born from May mating than from March mating.

Sire breed affected all traits (Table 4; $P < 0.001$). Romanov-sired ewes had the heaviest litter birth weight followed by Finnsheep- and Montadale-sired ewes. Texel-sired ewes had the lightest birth litter weight. Romanov-sired ewes had the greatest number of dam-reared lambs at weaning. Texel- and Montadale-sired ewes had the least number of dam-reared lambs at weaning. Romanov- and Finnsheep-sired ewes had more nursery-reared lambs at weaning and heavier nursery-reared litter weaning weights than Dorset-, Texel-, and Montadale-sired ewes. Romanov-sired ewes had the heaviest dam-reared litter weaning weight, whereas Texel-sired ewes had the lightest litter weight. Fall mating season when ewes were 1, 2, and 3 yr of age was a significant main effect for number and litter

Table 3. Levels of significance, least squares means, and SEM for the interaction of spring mating season × sire breed for traits measured to weaning

				Weaning trait[b]			
		Birth trait[b]		Number		Litter weight, kg	
Item	Fertility rate, %[a]	Number born	Litter weight, kg	Dam-reared	Nursery-reared	Dam-reared	Nursery-reared
Significance (*P*-value)	<0.001	0.027	0.079	0.108	0.111	0.186	0.310
Least squares means							
March × Dorset	82.6	1.37	6.61	0.95	0.13	18.3	1.4
March × Finnsheep	91.5	2.00	7.72	1.14	0.51	20.2	4.7
March × Texel	89.6	1.39	6.40	0.98	0.17	17.1	1.7
March × Romanov	92.4	2.12	8.27	1.34	0.43	23.8	4.3
March × Montadale	87.7	1.37	6.82	1.00	0.14	19.1	1.5
May × Dorset	62.5	1.55	7.08	1.13	0.12	21.6	1.1
May × Finnsheep	72.3	1.94	7.33	1.15	0.32	19.3	3.0
May × Texel	52.2	1.41	6.19	0.88	0.21	15.2	1.9
May × Romanov	89.2	2.05	8.08	1.25	0.40	22.6	3.8
May × Montadale	52.0	1.51	7.25	1.01	0.14	18.7	1.3
SEM	3.5	0.06	0.24	0.06	0.05	1.2	0.5

[a]Per ewe exposed.
[b]Per ewe lambing.

weight of dam-reared lambs at weaning. Ewes that were bred at 1, 2, and 3 yr of age in the December mating season had more lambs and heavier litter weights than those from the August and October seasons. No significant differences were detected between the two dam breeds.

Traits Measured at 20 wk of Age

The interaction of spring mating season × sire breed was significant for number of dam-reared lambs, dam-reared litter weight per ewe exposed, and total productivity for dam-reared lambs per ewe entering the breeding flock (Table 5). In both spring mating seasons, Romanov-sired ewes had more lambs; produced the heaviest litters; and, consequently, had the greatest total productivity. The productivity of Romanov-sired ewes was similar in March and May mating seasons. Texel- and Montadale-sired ewes were generally less productive for these three traits in the May mating season than in the March mating season.

Table 6 presents main effects for traits measured at 20 wk of age. For number of nursery-reared lambs, litter weight of nursery-reared lambs per ewe lambing, and litter weight of nursery-reared lambs per ewe exposed, Romanov- and Finnsheep-sired ewes produced the most lambs and the heaviest litters ($P < 0.05$). The Dorset-, Texel-, and Montadale-sired ewes produced a similar number of lambs and litter weights. Total productivity of nursery-reared lambs was greatest for Romanov-sired ewes, intermediate for Finnsheep-sired ewes, and least for Dorset-, Texel-, and Montadale-sired ewes ($P < 0.05$). Romanov-sired ewes produced the heaviest litter weight of dam-reared lambs per ewe lambing, whereas Texel-sired ewes produced the lightest litters ($P < 0.05$). Ewes mated in May had greater ($P < 0.05$) litter weight of dam-reared lambs per ewe lambing than ewes mated in March. Fall mating season when ewes were 1, 2, and 3 yr of age affected ($P < 0.05$) litter weight of dam-reared lambs per ewe exposed, total productivity of dam-reared lambs, and longevity. For the first two traits, ewes that bred at 1, 2, and 3 yr of age in the December mating season had heavier litter weights and a greater total productivity than ewes that bred at 1, 2, and 3 yr of age in August and October. Ewes that bred during the August mating season at 1, 2, and 3 yr of age had shorter longevity than ewes bred in the other two mating seasons. No significant differences were detected between the two dam breeds.

Discussion

Relative economic values of traits are necessary to guide selection among breeds for use in crossbreeding systems. Wang and Dickerson (1991a,b,c) developed a computer model of sheep production to investigate the relative effects of genetic changes in various traits on biological efficiency throughout the life cycle. For the common annual production system of fall breeding and spring lambing, biological efficiency was most influenced by fertility rate, prolificacy, and lamb survival. Length of seasonal fertility was a critical component of biological efficiency in production systems that incorporated spring breeding; however, Notter (1992) stated that no traditional breed in the US was sufficiently aseasonal to achieve high fertility throughout the year. Because the seasonal nature of fertility is a major constraint of the American sheep industry, an industry priority is to identify and/or develop breeds that are highly fertile during the entire year (Notter, 2002). Accordingly, the primary objective of this phase of the experiment was to estimate effects of sire breeds on

Table 4. Levels of significance, least squares means, and SEM for the main effects of sire breed, dam breed, spring mating season, and fall mating season for traits measured to weaning

		Birth trait[a]		Weaning trait[a]			
				Number		Litter weight, kg	
Item	Fertility rate, %[b,c]	Number born[c]	Litter weight, kg	Dam-reared	Nursery-reared	Dam-reared	Nursery-reared
Sire breed							
Significance (*P*-value)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Least squares means							
Dorset	72.5	1.46	6.84^{y}	1.04^{xy}	0.13^{x}	20.0^{x}	1.3^{x}
Finnsheep	81.9	1.98	7.53^{x}	1.15^{x}	0.42^{w}	19.9^{x}	3.9^{w}
Texel	70.9	1.40	6.30^{z}	0.93^{z}	0.19^{x}	16.2^{y}	1.8^{x}
Romanov	90.8	2.09	8.18^{w}	1.29^{w}	0.42^{w}	23.2^{w}	4.0^{w}
Montadale	69.8	1.44	7.04^{xy}	1.01^{yz}	0.14^{x}	18.9^{x}	1.4^{x}
SEM	2.6	0.05	0.18	0.05	0.04	0.9	0.3
Dam breed							
Significance (*P*-value)	0.736	0.909	0.299	0.185	0.707	0.370	0.857
Least squares means							
Composite III	76.8	1.67	7.11	1.11	0.26	19.9	2.5
Northwestern whiteface	77.5	1.68	7.25	1.06	0.25	19.3	2.5
SEM	1.5	0.03	0.10	0.03	0.02	0.6	0.2
Spring mating season							
Significance (*P*-value)	<0.001	0.233	0.862	0.977	0.174	0.764	0.113
Least squares means							
March	88.8	1.65	7.16	1.08	0.28	19.7	2.7
May	65.6	1.69	7.19	1.08	0.24	19.5	2.2
SEM	1.5	0.02	0.10	0.03	0.02	0.5	0.2
Fall mating season[d]							
Significance (*P*-value)	0.206	0.063	0.402	0.049	0.493	0.045	0.729
Least squares means							
August	77.6	1.65	7.17	1.05^{x}	0.24	18.9^{x}	2.3
October	74.8	1.64	7.08	1.05^{x}	0.28	19.1^{x}	2.6
December	79.2	1.73	7.28	1.14^{w}	0.26	20.8^{w}	2.5
SEM	1.9	0.03	0.12	0.03	0.02	0.6	0.2

[a]Per ewe lambing.
[b]Per ewe exposed.
[c]Interaction between sire breed and spring mating season was significant for these traits, $P < 0.05$. Thus, pairwise comparison of main effects was excluded.
[d]Effects of fall mating seasons at 1, 2, and 3 yr of age on reproductive traits of F_1 ewes joined during spring mating seasons at 4, 5, and 6 yr of age.
[w,x,y,z]Within a trait and source of variation, means that do not have a common superscript differ, $P < 0.05$.

fertility rates of mature F_1 ewes during March and May mating seasons.

Dorset and Finnsheep breeds are commonly used in spring-breeding production systems because of their high fertility rates relative to other breeds. In the current experiment, fertility rates of Finnsheep-sired ewes were approximately 10% greater than Dorset-sired ewes in both the March and May mating seasons. These results are consistent with previous research that reported greater fertility of Finnsheep ewes compared with Dorset in mid to late spring (Lamberson and Thomas, 1982; Quirke et al., 1985, 1988). Fertility rates of Texel- and Montadale-sired ewes were greater than F_1 ewes by Dorset sires in March, but 10% less in May. These experimental results do not support use of Texel or Montadale F_1 ewes for breeding in late spring.

Romanov-sired ewes were highly fertile in March (92%), but unlike F_1 ewes of other sire breeds, they had only a slight decrease in fertility in May (89%). Fertility rate of Romanov-sired ewes in May was 17 and 27% greater than that of Finnsheep- and Dorset-sired ewes, respectively. Current results are consistent with data of Valls Ortiz (1983), who reported that fertility rate of purebred Romanov ewes during June was 27% greater than that of purebred Finnsheep ewes. The extraordinary fertility rate of Romanov-sired ewes in May documents the superior direct breed effect of Romanov relative to Finnsheep and Dorset, breeds widely used in spring-breeding production systems. Greater use of Romanov crossbred ewes is justified to increase fertility rate during spring mating.

Interpretation of effects of sire breeds on number of lambs and litter weights at birth, weaning, and 20 wk of age per ewe lambing is similar to results reported for fall mating seasons (Casas et al., 2004). Briefly, Romanov-sired ewes were most productive, followed by Finnsheep, then Dorset and Montadale, and finally Texel.

Table 5. Levels of significance, least squares means, and SEM for the interaction of spring mating season × sire breed for traits measured at 20 wk of age

Item	Number[a]		Litter weight, kg				Total productivity, kg		
	Dam-reared	Nursery-reared	Dam-reared[a]	Nursery-reared[a]	Dam-reared[b]	Nursery-reared[b]	Dam-reared[c]	Nursery-reared[c]	Longevity, %[c]
Significance (*P*-value)	0.047	0.262	0.100	0.378	0.001	0.142	0.008	0.399	0.326
Least squares means									
March × Dorset	0.91	0.13	39.1	4.8	32.5	4.3	66.1	7.3	26.5
March × Finnsheep	1.07	0.45	42.8	16.4	38.5	14.7	72.1	25.6	25.2
March × Texel	0.93	0.14	36.9	5.4	32.9	5.0	58.1	6.8	26.5
March × Romanov	1.30	0.39	52.9	14.3	46.6	13.0	111.8	29.9	39.5
March × Montadale	0.99	0.11	41.9	4.1	36.8	3.7	79.8	6.6	39.2
May × Dorset	1.11	0.12	50.3	4.5	32.0	3.1	73.9	8.0	44.1
May × Finnsheep	1.15	0.30	48.2	11.7	34.0	9.1	68.0	17.5	29.1
May × Texel	0.83	0.18	35.2	6.2	17.5	3.2	35.2	5.9	34.2
May × Romanov	1.21	0.39	53.2	14.9	47.4	13.6	111.0	30.8	39.2
May × Montadale	0.99	0.11	44.0	3.9	22.2	2.4	49.6	6.4	41.2
SEM	0.06	0.05	2.8	1.7	2.7	1.4	6.6	2.6	5.0

[a]Per ewe lambing.
[b]Per ewe exposed.
[c]Per ewe entering breeding flock.

Table 6. Levels of significance, least squares means, and SEM for the main effects of sire breed, dam breed, spring mating season, and fall mating season for traits measured at 20 wk of age

Item	Number[a]		Litter weight, kg				Total productivity, kg		
	Dam-reared[b]	Nursery-reared	Dam-reared[a]	Nursery-reared[a]	Dam-reared[b,c]	Nursery-reared[c]	Dam-reared[b,d]	Nursery-reared[d]	Longevity, %[d]
Sire breed									
Significance (*P*-value)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.084
Least squares means									
Dorset	1.01	0.12[y]	44.7[y]	4.6[y]	32.2	3.7[y]	70.0	7.9[z]	35.3
Finnsheep	1.11	0.38[x]	45.5[y]	14.0[x]	36.3	11.9[x]	70.1	21.5[y]	27.2
Texel	0.88	0.16[y]	36.0[z]	5.8[y]	25.2	4.1[y]	46.7	6.4[z]	30.4
Romanov	1.25	0.39[x]	53.0[x]	14.6[x]	48.0	13.3[x]	111.4	30.4[x]	39.4
Montadale	0.99	0.11[y]	42.9[y]	4.0[y]	29.5	3.1[y]	64.7	6.5[z]	40.2
SEM	0.05	0.03	2.2	1.3	2.0	1.0	5.1	2.0	3.9
Dam breed									
Significance (*P*-value)	0.240	0.798	0.225	0.947	0.562	0.964	0.768	0.931	0.733
Least squares means									
Composite III	1.07	0.24	45.5	8.6	34.7	7.2	73.1	14.4	35.0
Northwestern whiteface	1.02	0.23	43.4	8.6	33.7	7.2	72.0	14.6	34.0
SEM	0.03	0.02	1.3	0.8	1.2	0.6	3.0	1.2	2.2
Spring mating season									
Significance (*P*-value)	0.649	0.388	0.044	0.481	<0.001	0.028	0.010	0.341	0.032
Least squares means									
March	1.04	0.25	42.7	9.0	37.9	8.1	77.6	15.3	31.4
May	1.06	0.22	46.2	8.2	30.6	6.3	67.6	13.7	37.6
SEM	0.03	0.02	1.3	0.8	1.2	0.6	3.0	1.2	2.3
Fall mating season[e]									
Significance (*P*-value)	0.056	0.519	0.076	0.528	0.015	0.708	<0.001	0.227	0.005
Least squares means									
August	1.02	0.22	43.1	8.1	33.3[y]	6.9	62.9[y]	12.5	27.7[y]
October	1.02	0.25	43.3	9.4	32.2[y]	7.7	70.1[y]	15.7	37.5[x]
December	1.11	0.23	46.9	8.4	37.3[x]	7.1	84.7[x]	15.3	38.2[x]
SEM	0.03	0.02	1.5	0.9	1.4	0.7	3.6	1.4	2.6

[a]Per ewe lambing.
[b]Interaction between sire breed and spring mating seasons was significant for these traits, $P < 0.05$. Thus, pairwise comparison of main effects was excluded.
[c]Per ewe exposed.
[d]Per ewe entering breeding flock.
[e]Effect of fall mating seasons at 1, 2, and 3 yr of age on reproductive traits of F_1 ewes joined during spring mating seasons at 4, 5, and 6 yr of age.
[x,y,z]Within a trait and source of variation, means that do not have a common superscript differ, $P < 0.05$.

Table 7. Performance of F_1 sheep for key traits by sire breed

	Sire breed					
Trait	Romanov	Finnsheep	Dorset	Texel	Montadale	SEM
F_1 lamb[a]						
Survival, %	94.1	93.0	90.0	90.7	89.1	1.2
ADG, g/d	278	272	285	267	282	3
Lean wt, kg	17.67	17.70	17.80	17.77	17.84	0.05
F_1 ewe						
Fall mating[b]						
Fertility, %	89.1	83.2	78.1	79.9	75.0	1.2
No. born	2.20	2.05	1.45	1.41	1.44	0.03
Longevity, %	76.8	70.5	65.9	68.7	76.3	2.5
Total productivity, kg	155	125	103	98	107	4
Clean fleece wt, kg	2.07	2.08	2.14	2.32	2.35	0.04
Wt of mature ewe, kg	74.3	75.5	80.1	75.5	80.8	0.6
Spring mating[c]						
Fertility, %	90.8	81.9	72.5	70.9	69.8	2.6
No. born	2.09	1.98	1.46	1.40	1.44	0.05
Longevity, %	39	27	35	30	40	4
Total productivity, kg	111	70	70	47	65	5

[a]Traits were recorded on F_1 lambs produced from August, October, and December matings (Freking and Leymaster, 2004). Survival of lambs to weaning at 8 wk of age was determined. Postweaning ADG was measured from 10 to 20 wk of age. Weight of lean in 28.75-kg carcasses was predicted for wethers produced from October mating.

[b]Traits were recorded on F_1 ewes mated in August, October, and December to lamb at 1, 2, and 3 yr of age (Casas et al., 2004; Lupton et al., 2004). Fertility rate was determined on ewes present at lambing. Number born was measured on ewes that lambed. Longevity was measured as percentage of ewes in the breeding flock at 42 mo of age. Total productivity through 3 yr of age for each ewe was calculated as the sum of 20-wk weights of dam-reared lambs. Fleeces were collected from 2-yr-old ewes. Weight of mature ewes was estimated as the weight of 3-yr-old ewes at breeding.

[c]Traits were recorded on F_1 ewes mated in March and May at 4, 5, and 6 yr of age (this paper). Fertility rate was determined on ewes present at lambing. Number born was measured on ewes that lambed. Longevity was measured as the percentage of ewes in the breeding flock 7 mo after mating at 6 yr of age (this paper). Total productivity from 4 to 6 yr of age for each ewe was calculated as the sum of 20-wk weights of dam-reared lambs.

For convenience purposes, results from three distinct phases of this comprehensive experiment (F_1 lambs, F_1 ewes in fall mating seasons, and F_1 ewes in spring mating seasons) are summarized by sire breed for key traits (Table 7). As described earlier, research by Wang and Dickerson (1991a,b,c) revealed that fertility rate, prolificacy, and survival (lamb and ewe) were traits with the greatest effect on biological efficiency. Inspection of sire breed means for these essential traits differentiates Romanov and Finnsheep from Dorset, Texel, and Montadale. Overall, the latter three sire breeds were fairly similar to each other, although Texel-sired sheep tended to be somewhat less productive than Dorset and Montadale, particularly in spring mating seasons. In contrast, F_1 progeny of Romanov and Finnsheep sires differed from one another. Romanov-sired ewes had greater fertility rate, length of seasonal fertility, prolificacy, and longevity compared with Finnsheep-sired ewes. Consequently, in fall mating seasons, total productivity (dam-reared lambs) through 3 yr of age of Romanov-sired ewes exceeded Finnsheep-sired ewes by 24%. In spring mating seasons, total productivity from 4 through 6 yr of age was 59% greater for Romanov-sired ewes than for F_1 ewes by Finnsheep sires.

Based on these experimental results, greater industry use of Romanov crossbred ewes in maternal roles of terminal crossbreeding systems is recommended, especially for annual or accelerated production systems that breed in the spring.

Implications

We previously reported exceptional reproduction of Romanov-sired crossbred ewes during traditional fall breeding (August, October, and December); however, the seasonal nature of sheep fertility is an important economic constraint of the industry. Length of seasonal fertility largely determines the effectiveness of accelerated systems (three lamb crops in 2 yr or five lamb crops in 3 yr) and annual systems that breed in the spring. An experiment was conducted to compare fertility rates during March and May breeding of mature crossbred ewes sired by Dorset, Finnsheep, Romanov, Texel, and Montadale rams. Romanov-sired ewes were 59% more productive than Dorset and Finnsheep (breeds commonly used for out-of-season breeding), primarily as a result of greater fertility rate and prolificacy in both seasons. Efficiency of commercial sheep production could be improved markedly by greater use of Ro-

manov-crossbred ewes in maternal roles of terminal crossbreeding systems.

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